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Computed tomographic signs of periodontal disease of equine cheek teeth: a retrospective study in 49 horses

Inaugural-Dissertation

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Meiner Familie

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1. Einleitung und Zielsetzung

In der Vergangenheit wurde das Pferd vor allem als Arbeitstier genutzt, wobei das Hauptaugenmerk der damaligen Zahnbehandlungen auf eine optimale Futteraunahme/-verwertung gerichtet war. In den letzten Jahren hat sich die Nutzung des Pferdes sehr stark in Richtung freizeitmässiger und sportlicher Nutzung gewandelt. Dies hat auch die Anforderungen an die Zahnmedizin beim Pferd verändert und gleichzeitig hat die Pferdezahnheilkunde enorm an Bedeutung gewonnen. Zudem ist in der heutigen Pferdehaltung die Langlebigkeit der Pferde zu einer wichtigen Aufgabe geworden. In einer Studie von Ireland (2012) wurden bei 200 geriatrischen Pferden (Alter > 15-jährig) in 95.4% Zahnpathologien wie Diastema, Hackenzähne, Wellen- und Scherengebisse festgestellt. Gerade auch wegen den immer älter werdenden Pferden ist die regelmässige Zahnbehandlung zu einer wichtigen Pflegemassnahme der heutigen Pferdehaltung geworden. Da von der Norm abweichende Zahnstellungen, ob angeboren oder erworben, zu einer ungleichmässigen Belastung der Kauflächen und somit des Kiefergelenks führen, ist das Erreichen einer Normokklusion erwünscht (Simon 2009). Weiter werden endodontische und andere fortschrittliche zahnerhaltende Therapien sowie Zahnextraktionen vorgenommen. Somit benötigt der Tierarzt nicht nur ein breites fachliches Wissen auf dem Gebiet der Zahnmedizin, sondern auch auf dem Gebiet der Chirurgie und der Medizin. Um Zahnpathologien besser verstehen zu können, ist es zudem essentiell, die hochkomplexe Anatomie der hypsodonten Pferdezähne, welche sich im Alter kontinuierlich verändern, sowie die verschiedenen Kompartimente der Nasennebenhöhlen zu verstehen (Windley 2009).

Häufig werden die ersten Anzeichen einer Zahnveränderung von den Besitzern nicht bemerkt. Im Gegensatz zu den Zahnerkrankungen des Menschen erscheinen viele

Pathologien am Pferdezahn zu Beginn wenig bis nicht schmerzhaft. Dies bedeutet, dass die Pferde dem Tierarzt meist erst mit einer fortgeschrittenen Zahnpathologie vorgestellt werden, nämlich dann, wenn sich Symptome wie Anorexie, Verhaltensauffälligkeiten, stinkender eitriger Nasenausfluss oder eine äusserliche Schwellung am Gesichtsschädel zeigen. Für diese Symptome kommen – je nach Pferdealter – viele verschiedene Differentialdiagnosen in Frage. Durch das relativ späte Auftreten der klinischen Symptome sind häufig bereits erhebliche Sekundärpathologien in der direkten Umgebung des betroffenen Zahnes entstanden. Dazu zählen Veränderungen wie septische Sinusitiden, Bildung von Sinuszysten, Zahnwurzelgranulomen, Osteitis und Knochenlyse. Bei solchen Symptomen reicht aufgrund der Anatomie und der Lokalisation der häufigsten Zahnpathologien eine Maulhöhlenuntersuchung alleine nicht mehr aus. Aus diesem Grund sind qualitativ hochstehende bildgebende Verfahren von grossem Nutzen. Dazu stehen heute viele diagnostische Möglichkeiten zur Verfügung. Neben der manuellen Exploration der Maulhöhle, der Zahnendoskopie und den radiologischen Untersuchungen, haben die Schnittbildtechniken wie Computer- und Magnetresonanztomographie stark an Bedeutung gewonnen. Bei der manuellen Exploration achtet man auf Zahnlücken, wackelnde Zähne und den Geruch. Bei der Zahnendoskopie beurteilt man die Schleimhaut, die Zahnlücken und die Kauflächen der Zähne genauer. Mit dem Röntgenbild kann man die einzelnen Zahnkronen und -wurzeln, sowie die verschiedenen Stirn- und Kieferhöhlen beurteilen. Nachteile des Röntgenbildes sind die zweidimensionale Betrachtungsweise und die vielen Überlagerungen der einzelnen knöchernen Strukturen. Die Computertomographie (CT) hat viele Vorteile, jedoch auch gewisse Einschränkungen. Die Aufnahmen sind aufgrund der Grösse der Pferde auf die Extremitäten bis und mit Carpus/Tarsus, den Kopf und die Halswirbelsäule bis ca. zum 4. Halswirbel beschränkt. Es ist bei einem erwachsenen

Pferd nicht möglich das Becken oder das Knie in der Computertomographie zu beurteilen, obwohl dies durchaus sehr interessant und klinisch von Relevanz wäre. Die Vorteile liegen in der überlagerungsfreien Darstellung der Strukturen des Kopfes, der Möglichkeit der dreidimensionalen Betrachtungsweise und in der exzellenten Auflösung insbesondere der Knochenstruktur. Bereits in den ersten Beschreibungen in den 80er Jahren über die Technik und Anwendung der Computertomographie beim Pferd wurde auf die besondere Attraktivität im Bereich des Kopfes hingewiesen (Barbee 1986; Barbee 1987).

In dieser Dissertation wurden bei 49 Pferden die Zahnstrukturen gesunder und pathologischer Oberkieferbackenzähne mit einem Mehrschicht-Computertomographen untersucht und ausgewertet. Die Prävalenz von Zahnpathologien wie Zahnfraktur, Infundibularnekrose, Pulpitis, Wurzelabrundungen, periapikale Sklerose und verbreiterter Periodontalraum wurden erhoben. Ein wesentliches Augenmerk wurde der Beurteilung der Lamina dura beigemessen. Die Lamina dura ist der Bereich des alveolären Knochens, an dem die Sharpeyschen Fasern inserieren. Es handelt sich dabei um eine dünne, kompakte Schicht, die bei gesunden Zähnen radiologisch gut darstellbar ist (Dixon 1999). In den bisherigen Studien über die Computertomographie wurde diese Struktur nicht näher untersucht (Tietje 1996; Morrow 2000; Henninger 2003; Veraa 2009; Windley 2009; Huggons 2011).

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2. Manuskript

2.1 Zusammenfassung

In dieser Arbeit wurden CT-Studien von 49 Pferden im Zeitraum Februar 2008 – Juni 2010 retrospektiv ausgewertet. Alle Tiere gehörten zum Patientengut der Vetsuisse-Fakultät Zürich. Es wurden nur Pferde in die Studie eingeschlossen, bei denen eine vollständige CT-Studie des Kopfes, d.h von den Incisivi bis und mit Siebbein, vorhanden war.

Die CT-Daten wurden mit einer Schichtdicke von 1.5 mm rekonstruiert. Ausgewertet wurden Hinweise auf Paradontalerkrankungen für jeden Backenzahn und jede einzelne Wurzel. Geachtet wurde auf Zahnpathologien wie Zahnfraktur, Infundibularnekrose, Pulpitis, Wurzelveränderungen, periapikale Sklerose, Veränderungen des Periodontalraumes und der Verlust der Lamina dura.

Insgesamt wurden 588 Backenzähne und 1764 Wurzeln ausgewertet. An mindestens einem Oberkieferbackenzahn hatte jedes Pferd Anzeichen einer Paradontalerkrankung und bei 85% der untersuchten Wurzeln fand man verschiedene Grade von paradontalen Abnormalitäten. Der Verlust der Lamina dura wurde bei 75.9% der Wurzeln (Prämolare und Molare) gefunden. Andere Veränderungen waren vergleichsweise selten (1.5 - 6.8% der betroffenen Zähne oder Wurzeln).

Die sehr hohe Prävalenz einer unvollständigen oder nicht vorhandenen Lamina dura bei Zähnen ohne weitere pathologische CT-Befunde spricht dafür, dass das Fehlen der Lamina dura einer physiologischen Normvariante entspricht. Die klinische Relevanz des Verlustes der Lamina dura im CT sollte deshalb mit Vorsicht interpretiert werden.

2.2 Summary

CT studies of the head of 49 horses, which were scanned at the University of Zurich from February 2008 to June 2010, were evaluated retrospectively. Only horses with a complete CT investigation of the head (from the incisivi to the ethmoid) where included in the study.

The data were reconstructed to image series with 1.5 mm slice thickness. They evaluated the presence or absence of specific CT signs of periodontal disease for each cheek tooth and root (rostral, medial, caudal) in every case. The following CT signs were assessed: tooth fracture, infundibular necrosis, pulpitis, clubbing of the root, periapical sclerosis, widened periodontal space and loss of lamina dura.

Overall, 588 upper cheek teeth and 1764 roots were evaluated. Dental disease after CT investigation was common and seen in at least one cheek tooth root of each horse and 85% of all investigated roots. Loss of the lamina dura was found in 75.9% of affected roots and likewise seen in all premolar and molar cheek teeth. The other CT abnormalities were rare (1.5-6.8% affected teeth or roots).

The high prevalence of an absent or partiell existing lamina dura of teeth without other patologic CT-signs shows that loss of lamina dura represents a variation from the norm. However, loss of lamina dura diagnosed with multi-slice CT should be interpreted with caution to insure its clinical significance.

2.3 Introduction

Dental problems in horses account for 10-24% of the case load in equine veterinary practice (Baker 1983; Mueller 1991). Postmortem studies of horses that died or were subjected to euthanasia for reasons unrelated to dental problems have indicated a surprisingly high incidence of up to 80% of potentially clinically significant but undiagnosed dental abnormalities (Honma 1962; Wafa 1988; Kirkland 1994; Brigham and Duncanson 2000a). Dental diseases in horses include periodontitis, periapical infection with or without secondary sinusitis, infundibular caries, tooth fractures and pulpitis (Crabill and Schumacher 1998). Severe periodontal disease is often seen in horses with developmental disorders such as diastemata, displaced and supernumerary cheek teeth, but also in older animals with acquired abnormalities of wear, such as shear-mouth or wave-mouth, and acquired cheek teeth displacements (Dixon 1999). Localised periodontitis involving apically infected teeth was diagnosed in young horses, and generalised periodontitis in horses over 17 years of age (Weller 2001). Unfortunately, clinical signs such as malodorous nasal discharge, facial swelling, weight loss or draining fistulous tracts usually become apparent a considerable amount of time after the occurrence of the initial dental defect.

Identification of the affected tooth can be difficult. The diagnosis is based on the history and results of clinical examination and a detailed oral examination including endoscopy and radiography. Because of its wide availability, radiography is the most popular diagnostic technique for investigating disorders of the equine head (Barakzai 2006). Depending on the stage, periodontal disease has been defined as a combination of changes, which include widening of the periodontal space, pulpitis, loss of lamina dura, lysis of the tooth apex, rounding or clubbing of the tooth root, alveolar bone sclerosis, abnormal apical deposition of dental cementum, and the occurrence of predisposing changes such as dental aplasia or displacement (Baker

1970; Easley 1991; Soames 1993; Lane 1994; Dixon 1997; Dixon 1999). The radiographic assessment of the equine dental arcades, nasal cavity and maxillary sinuses is complicated by the size of the patient and superimposition of multiple anatomical structures. A recent study using digitally cropped radiographs reported a median sensitivity and specificity for apical tooth root infection of 76% and 90%, respectively (Townsend 2011). Based on an optimal balance between high sensitivity and specificity as well as agreement among clinicians, Townsend (2011) identified four specific radiographic signs (periapical sclerosis, periapical halo formation, clubbing of one or two roots and severity of clubbing) that were most consistent with apical infection of equine cheek teeth. Interestingly, loss of lamina dura was a very sensitive (90%) radiographic sign, but was also the least specific (34%) radiographic sign and characterised by very low interobserver agreement (Townsend 2011).

In the last decade, computed tomography (CT) has increased in importance in the diagnosis of equine dental problems. The technical benefits of CT are increased contrast resolution and the feasibility of cross-sectional images as well as multiplanar and three-dimensional (3D) reconstruction modes. Detection of early changes such as widening of the periodontal space or the loss of lamina dura is difficult using radiography (Townsend 2011). Computed tomography on the other hand generates sectional images and is superior to radiography because there is no superimposition of dental structures. Furthermore, changes in the density of tooth structures may be diagnosed at a much earlier stage. Multi-slice CT, which produces very thin slices (≤ 1 mm), increases spatial resolution and reduces partial volume artefacts, facilitating the detection of smaller lesions.

There have been several reports on the evaluation of equine teeth using CT. In an early report, hypoattenuation of the cementum, destruction of the enamel and filling of the infundibular cavity with gas because of caries were the most frequent CT findings in horses with dental disease (Henninger 2003). More recent studies described the normal and pathological CT appearance of the peripheral enamel, pulp, infundibular enamel and cementum in equine cheek teeth. A high prevalence of infundibular lesions was reported in two studies (Windley 2009; Fitzgibbon 2010), but another report showed no statistical relationship between infundibular caries and apical infection (Veraa 2009). In a study of mandibular cheek teeth, CT facilitated the identification of diseased teeth that appeared normal radiographically (Huggons et al. 2011). Parameters such as tooth pulp involvement, presence of bone fragments, cortical bone destruction, periosteal reaction of lingual and buccal mandibular bone and lamina dura destruction were more conspicuous on CT scans than on radiographs (Huggons et al. 2011). However, although loss of lamina dura is considered an early sign of apical infection of cheek teeth (Baker 1971; Gibbs and Lane 1987), there have been no studies evaluating this particular anatomical structure in relation to other CT signs of dental disease.

The purpose of the present investigation was to study the prevalence and relationship of CT signs of dental disease such as infundibular necrosis, tooth fracture, pulpitis, clubbing of the root, loss of lamina dura, periapical sclerosis and widened periodontal space in equine cheek teeth.

2.4 Materials and methods

Patients

Computed tomographic images of the head of horses that were scanned at our clinic from February 2008 to June 2010 were evaluated retrospectively. For inclusion in the study, cases had to meet the following criteria: 1) clinical signs suggesting dental disease (e.g. malodorous, purulent or sanguineous nasal discharge, facial swelling, fistulous tract formation, headshaking, anorexia); 2) other head abnormalities (head trauma, stridor, enophthalmus, head tilt and ataxia) and 3) a complete CT study of the maxillary dental arcades, the adjacent sinuses and the ethmoid bone. Horses that had undergone previous dental surgery were excluded.

All horses underwent clinical examinations, dental examinations and radiography of the head. Patients with nasal discharge, head trauma or headshaking also underwent endoscopy of the upper airways, and a complete neurological examination was carried out in head shakers.

Anaesthesia

Preoperatively cefquinom (Cobactan®)[1] 1 mg/kg i.v, phenylbutazone (Butadion®)[2] 1 mg/kg i.v. and tetanus-toxoid (Equilis Te®)[3] 150 I.E i.m. were administered. Each horse was sedated with xylazine-HCL (Xylazin Streuli®)[4] 1.1 mg/kg i.v.. Anaesthesia was induced with ketamine (Narketan®)[5] 2.2 mg/kg i.v. and climazolame (Climasol®)[6] 0.2 mg/kg i.v. and maintained with the same anaesthetics using a constant rate infusion.

CT examination

Transverse contiguous slices were obtained in a helical mode from the incisors to the cribriform plate with a 40-slice CT scanner.[7] Settings of 140 KV, 300 mAs, 1 s tube rotation, a pitch of 0.55, and an increment of 1.2 mm were used as well as a 3 mm slice collimation. The data were reconstructed to image series with 1.5 mm slice thickness using a medium-frequency image reconstruction algorithm (soft tissue) and a high-frequency image reconstruction algorithm (bone), respectively. Computed tomographic images were transferred to a workstation and reviewed by a board certified radiologist (SO) and the first author (MB) with dedicated software using multiplanar and 3D-reconstruction modes.[8] Two different windows were applied: a soft tissue window (window width, 400 Hounsfield units; window level, 40 Hounsfield units) and a bone window (window width, 1500 Hounsfield units; window level, 300 Hounsfield units). Data sheets evaluating the presence or absence of specific CT signs of periodontal disease, some with sub-categories (mild, moderate, severe), were compiled for each cheek tooth and root (rostral, medial, caudal) in all cases. The following CT signs were assessed: rostral or caudal infundibular necrosis, tooth fracture, pulpitis, clubbing of the root, loss of lamina dura, periapical sclerosis and widening of the periodontal space (>1 mm).

Statistics

To evaluate the association among the CT signs, logistic regression models were calculated at the level root with both forward and backward stepwise procedures, and the Wald method as well as the likelihood ratio method.[9] Each CT sign was once encountered a dependent variable while the remaining variables were entered as covariates. In a second step, mixed models were calculated to take the random effect of the individual horse and tooth number into account.[10] An association between variables was considered significant if the p-value was < 0.05 and the B-value was > 0.5 or < -0.5. The best model was chosen based on the lowest Akaike information criterion value.

2.5 Results

Forty-nine horses with a median age of 11.3 years (range 4 to 20 years) were included. There were 32 Warmblood horses, seven Thoroughbreds, three Quarter horses, one Friesian horse, one Spanish horse, one Icelandic horse, one Freiberg horse, 2 Welsh ponies and one horse of unknown breed.

A total of 588 upper cheek teeth with 1764 roots and 1176 infundibula were evaluated. Overall, all horses had signs of periodontal disease in at least one cheek tooth root. A total of 85% (1499) of all investigated roots had various degrees of periodontal abnormalities (Figs 1 to 4).

The absolute frequency of infundibular necrosis, tooth fracture, pulpitis, clubbing of the root, loss of lamina dura, alveolar bone sclerosis and widening of the periodontal space in the cheek teeth is shown in Table 1. Dental disease was most common in the 108/208, 109/209 and 110/210 (Figs 1 to 4). Infundibular necrosis was more frequently observed in the rostral than in the caudal infundibulum (Figs 3 and 7). Loss of lamina dura occurred in all premolar (106-108/206-208) and molar (109-111/209-211) cheek teeth (Figs 5 and 6), affecting 75.9% of all roots, and was therefore the most common lesion. Other abnormalities were rare (1.5 to 6.8% affected teeth or roots) and occurred mainly in the 108/208, 109/209 and 110/210 (Table 1).

The relative frequencies of single root abnormalities that were not associated with other CT changes were as follows: loss of lamina dura, 45.7%; alveolar bone sclerosis, 0.7%; clubbing of the root, 0.1% and widening of the periodontal space, 0.1% (Figs 1 to 4). Infundibular necrosis and tooth fracture were diagnosed as solitary tooth changes in only 6.7% and 0.1% of all upper cheek teeth, respectively.

Additional CT findings included soft tissue facial swelling in 10 horses (20.4%), thickening of the maxillary bone in 16 (32.7%) and destruction of the maxillary bone in 7 horses (14.3%) (Fig 4). Signs of sinusitis e.g. mucosal thickening, fluid or soft tissue material were identified in the nasal conchae in 18 horses (36.7%), in the paranasal sinuses in 29 horses (59.2%) and in the ethmoid bone in 12 horses (24.5%) (Figs 1 to 4). All logistic regression models (forward and backward stepwise procedure, Wald and likelihood ratio method) revealed the same significant associations among the different CT abnormalities. Results were confirmed by the mixed models (Table 2). With the exception of *infundibular necrosis* and *loss of lamina dura*, there were multiple significant and positive associations among the CT abnormalities *tooth fracture*, *pulpitis*, *clubbing of the root*, *alveolar bone sclerosis* and *widening of the periodontal space*. *Infundibular necrosis* was negatively associated with *tooth fracture*, i.e. these two CT signs did not occur together in the same tooth. There were no other significant associations between *infundibular necrosis* and other CT abnormalities. *Loss of lamina dura* was negatively associated with *periodontal widening*: an incomplete *lamina dura* was often seen accompanied by a normal *periodontal space width*. However, loss of lamina dura was significantly and positively associated with *pulpitis*, but not with other lesions. With the exception of *widening of the periodontal space*, the best model-fit was achieved for all CT signs if the random effects of the individual horse and tooth number were included in the model. For *widening of the periodontal space*, the best model included only the random effect of the individual horse.

2.6 Discussion

In the present study, CT signs of dental disease were common and seen in at least one cheek tooth root of each of 49 horses and 85% of all investigated roots. This was in agreement with the results of a previous study in which hypoattenuating infundibula were seen in 78 of 150 teeth with concurrent alveolar changes in 20 teeth and solitary alveolar changes in another 9 teeth (Veraa 2009).

Similar to other studies (Wafa 1988; Gorn 1992; Lane 1994; Crabill and Schumacher 1998; Lattimer 1998; Baker 1999; Henninger 2003; Veraa 2009), a large portion of CT changes occurred in the 108/208 as well as the 109/209 and 110/210. This appeared to be reflected in a better model fit if the tooth number was included as a fixed effect in the mixed models. It indicated that the tooth number had a significant effect on the occurrence of dental disease. The observation that tooth number and CT changes were linked can be explained, at least in part, by the absence of a protective deciduous cap in molars during eruption and by the fact that molars are older, shorter and more prone to dental wear (Dacre 2007). In clinical experience, the cheek teeth 308 and 408 often have protuberances that cause corresponding indentations in 108 and 208, which may lead to increased chronic occlusal pressure and a predisposition to disease in the latter.

Several horses in the present study underwent extraction of a cheek tooth but disease was not confirmed histologically. Histological examination is the gold standard for diagnosing dental disease, although it is technically difficult and expensive. Moreover, the horse population that we studied included clinical patients, and therefore dental surgery was only performed in the most severely affected tooth. For the statistical analyses, each CT sign was once encountered a dependent variable while the remaining variables were entered as covariates. Multiple significant associations among the CT abnormalities tooth fracture, pulpitis, clubbing of the root, alveolar bone sclerosis and widening of the periodontal space were found. It therefore appears that these CT changes are related and are all part of the same disease process. A likely disease process that combines all these signs is apical infection.

Among the investigated CT abnormalities, loss of lamina dura was most frequently seen, either in combination with other changes or as a solitary lesion. Loss of lamina dura occurred in all premolar (106-108/206-208) and molar (109-111/209-211) cheek teeth and was significantly associated only with pulpitis. Loss of lamina dura is considered an early sign of apical infection (Baker 1971; Gibbs 1987). The present report is the first to describe the prevalence of loss of lamina dura in the upper equine cheek teeth as assessed by CT. Another novel aspect of our study was the use of a multi-slice CT scanner with a slice thickness of 1.5 mm, which drastically reduced partial volume artefacts and possibly facilitated the detection of changes in the continuity, thickness and density of the lamina dura at an earlier stage. On the other hand, periodontal disease is uncommon in certain teeth such as the 106/206, 107/207 and 111/211. It appears unlikely that all the tooth roots diagnosed with loss of lamina dura and no other CT changes in our patients would have developed periodontal disease later in life. We therefore believe that a thin or incomplete lamina dura is a variation of normal. However, follow-up CT studies of affected tooth roots combined with histological examination are needed to test this hypothesis. In the mixed models, an intact lamina dura was linked with widening of the periodontal space.

In a recent study using a single-slice CT scanner, there was a high prevalence of infundibular necrosis and alveolar changes of the upper cheek teeth, but the two lesions were not related to each other statistically (Veraa 2009) and appeared to represent sole entities. Our findings confirmed this. Although infundibular necrosis was less common than previously reported (Veraa 2009), it was the second most common CT change. It was seen more frequently in the rostral infundibulum than in the caudal infundibulum. Furthermore, infundibular necrosis represented a solitary CT change that was not associated significantly with other CT signs of dental disease.

The effect of the individual horse also improved the model fit of the mixed models, suggesting that factors such as age (Dixon 2000; Weller 2001; Dixon 2005), breed, anatomical conformation and feeding play a role in the development of periodontal disease. We could not analyse these effects statistically because the majority of horses were middle-aged Warmbloods. Infundibular necrosis is rare or nonexistent in wild horses (Miles 1990), and it has been suggested that domestication has contributed to the aethiopathogenesis of infundibular disorders in horses (Fitzgibbon 2010). For widening of the periodontal space, the best model included only the random effect of the individual horse.

In summary, CT signs of dental disease were common in the present study population and predominantly occurred in the 108/208, 109/209 and 110/210. The association among various CT signs of apical infection was assessed. Tooth fracture, pulpitis, clubbing of the root, periapical sclerosis and widening of the periodontal space were statistically related to each other, whereas infundibular necrosis occurred as a solitary CT change that was not associated significantly with other CT signs of periodontal disease. Loss of lamina dura, either alone or in combination with other CT signs of apical infection, was by far the most common CT change. It is not clear whether this finding represents an early sign of apical infection or whether it is a variation of normal. Therefore, loss of lamina dura diagnosed with multi-slice CT should be interpreted cautiously.

Manufacturers' *addresses*

[1]Veterinaria AG, Churerstr. 158, 8808 Pfäffikon SZ, Switzerland

[2]Streuli Pharma AG, Bahnhofstr. 7, 8730 Uznach, Switzerland

[3]Veterinaria AG, Churerstr. 158, 8808 Pfäffikon SZ, Switzerland

[4]Streuli Pharma AG, Bahnhofstr. 7, 8730 Uznach, Switzerland

[5]Vétoquinol AG, Worblentalstr. 32, 3063 Ittingen, Switzerland

[6]Dr. E. Gräub AG, Bern, Rehhagstr. 83, 3018 Bern, Switzerland

[7]Sensation Open, Siemens Erlangen, Germany

[8]OsiriX Open Source™ Version 3.2.1, OsiriX Foundation, Geneva, Switzerland

[9]IBM SPSS Statistics, Version 19, Chicago, IL, USA

[10]R, version 2.14.0, The R Foundation for Statistical Computing, Vienna, Austria

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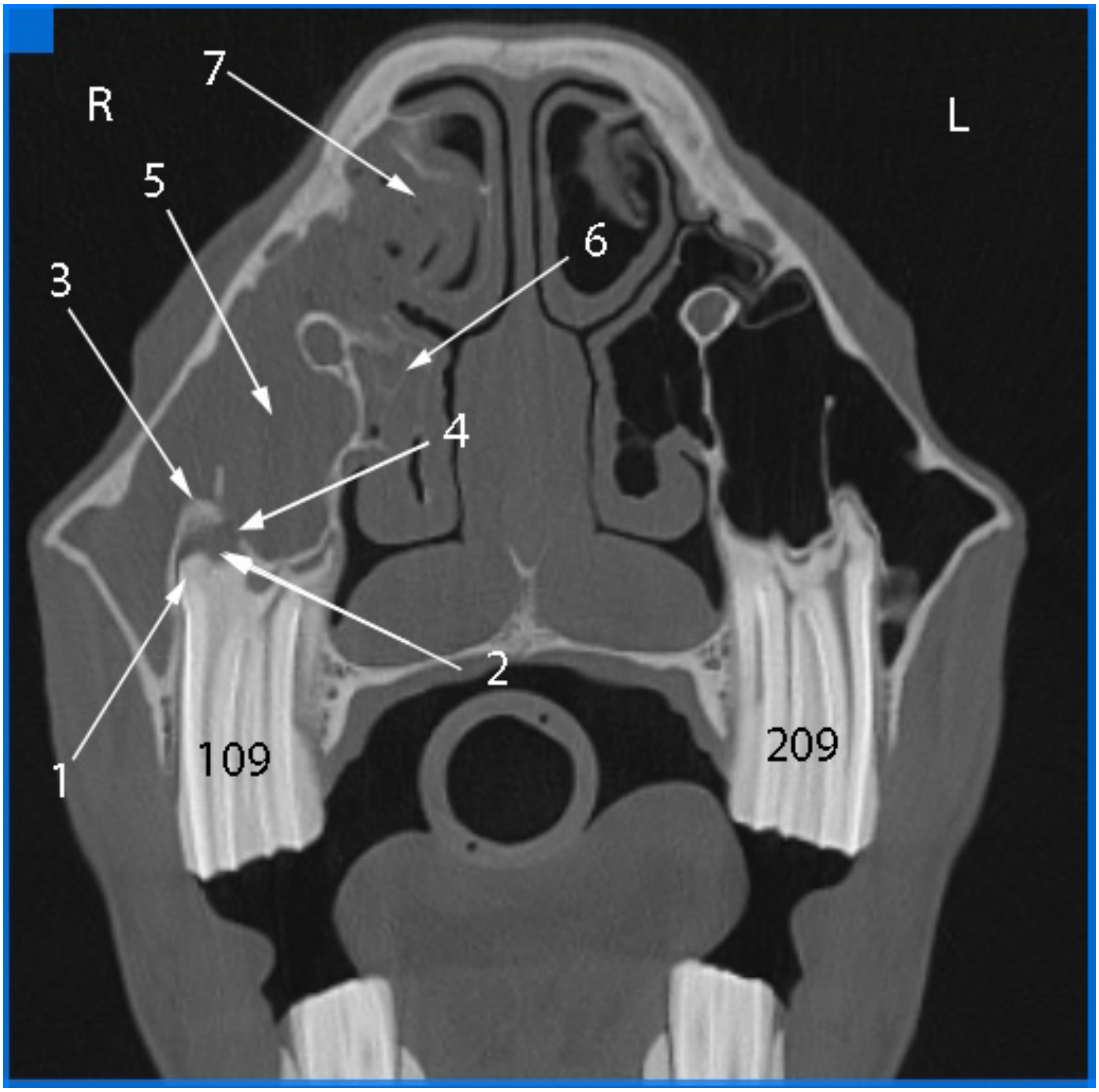
2.8 Appendix

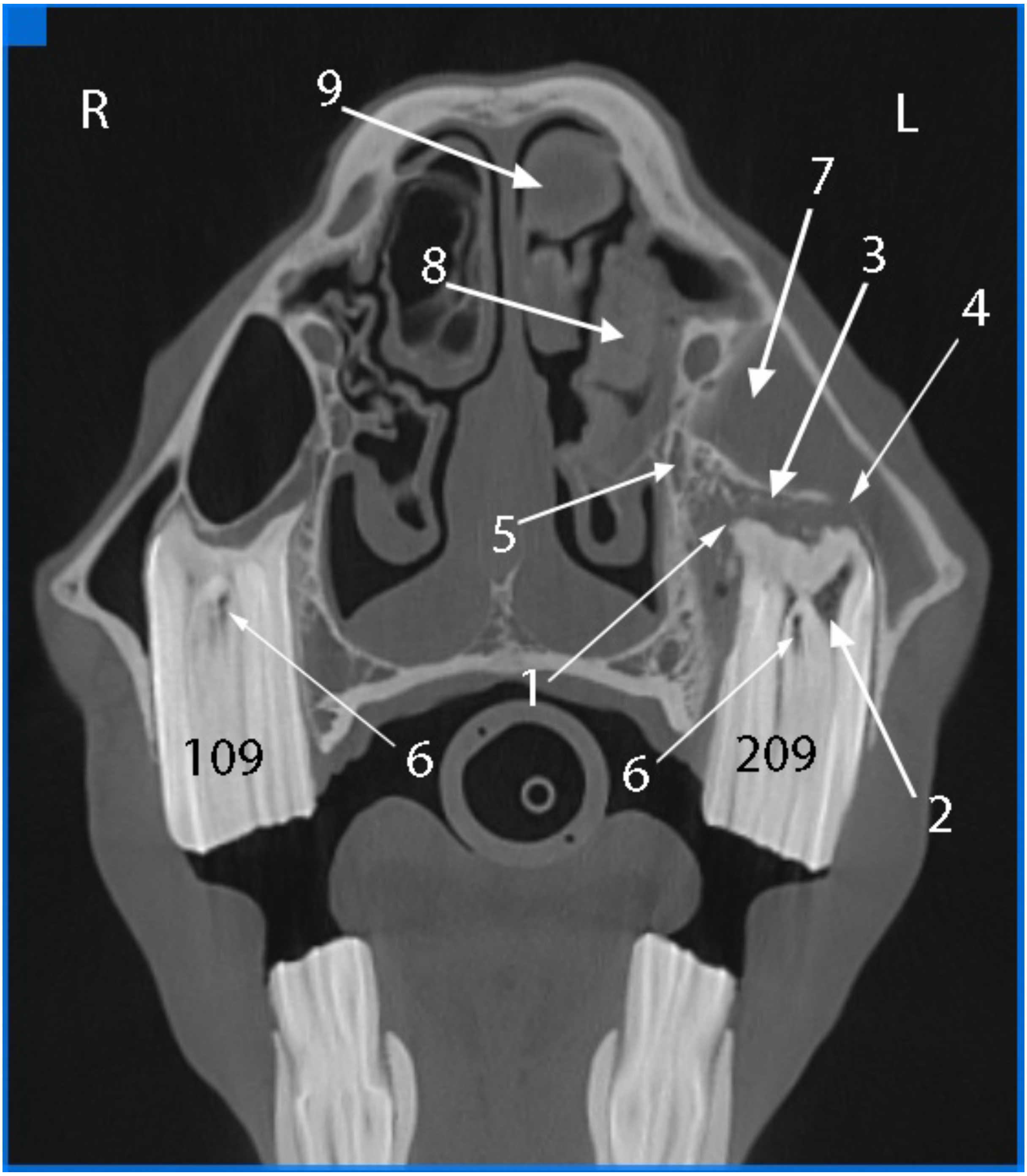
2.8.1 Figures

Figure 1:



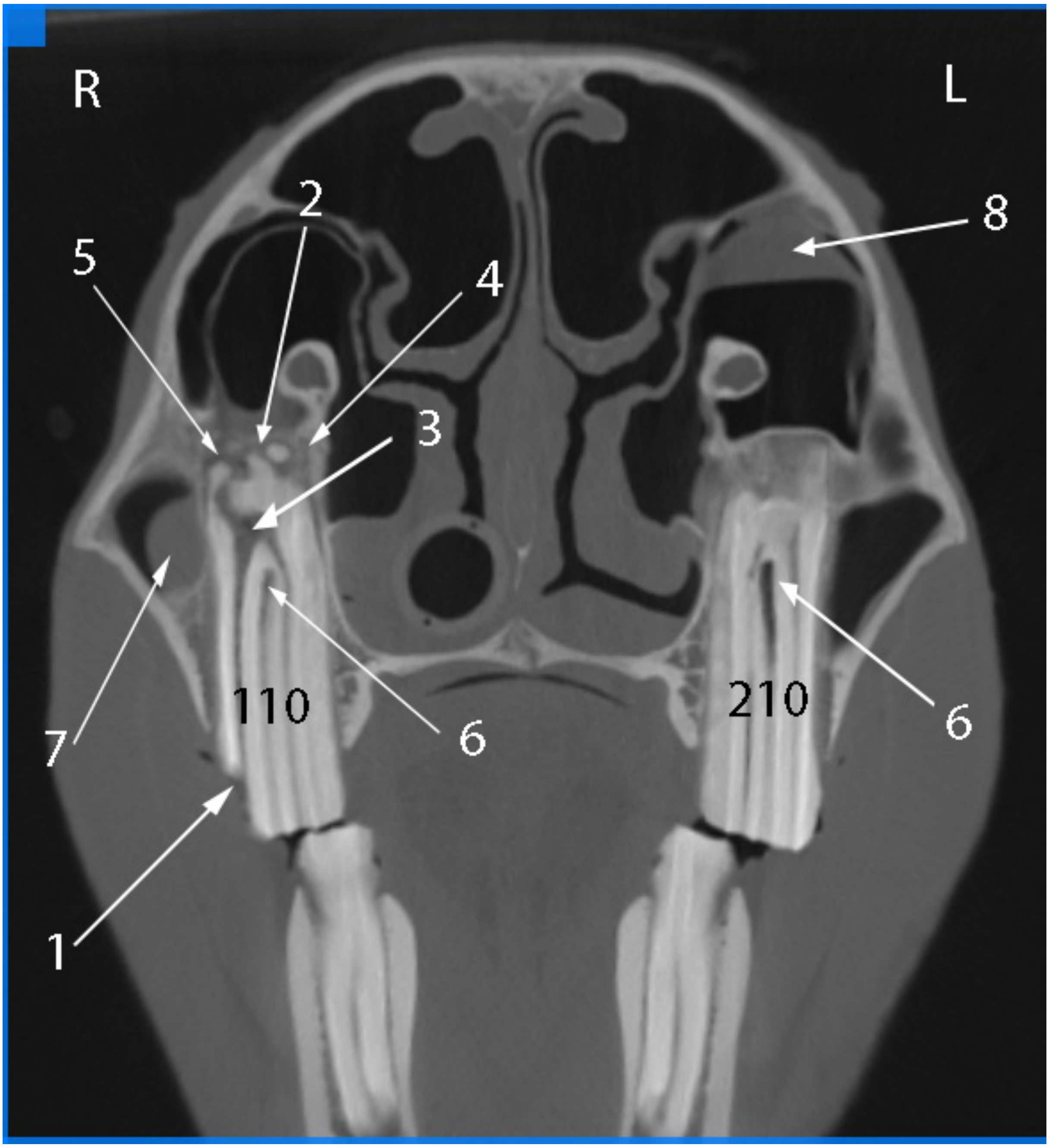
Transverse CT image at the level of the first molar teeth (medial and laterocaudal root) in a 12-year-old warmblood with malodorous nasal discharge since 1 month. There is severe apical infection of 109 (laterocaudal root) with clubbing of the root (1), widened periodontal space (2), sclerosis of the alveolar bone (3) and loss of lamina dura (4). The sinus maxillaris pars rostralis (5), the sinus conchae ventralis (6) and the sinus conchae dorsalis (7) are filled with soft tissue dense material.

Figure 2:



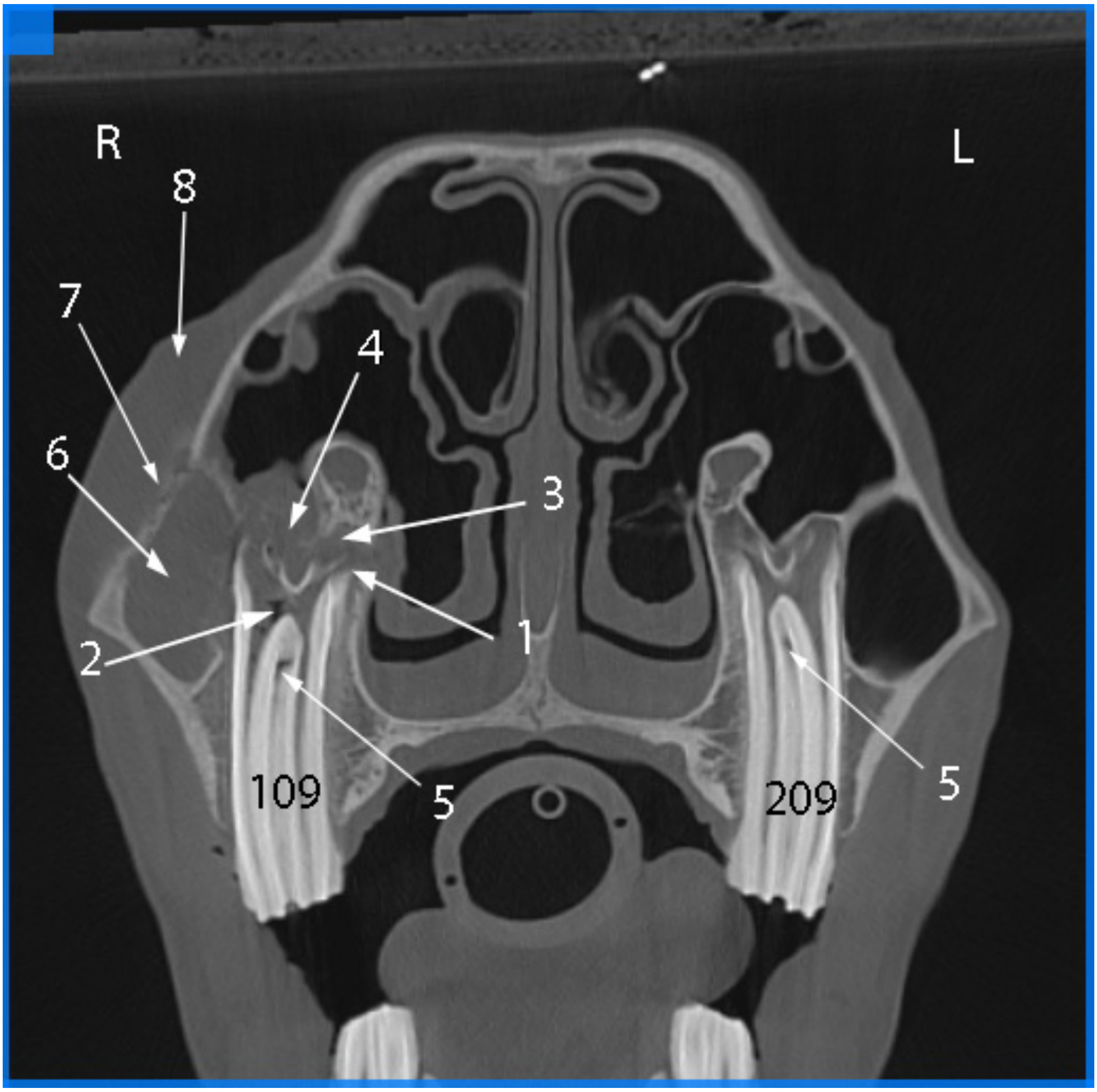
Transverse CT image at the level of the first molar teeth (medial and laterocaudal root) in a 11-year-old warmblood with malodorous nasal discharge since 4 months. There is severe apical infection of 209 (medial and laterocaudal root) with clubbing of the root (1), pulpitis (2), widened periodontal space (3), loss of lamina dura (4) and sclerosis of the alveolar bone (5). There is a slight hypoattenuating caudal infundibulum bilaterally (6). The sinus maxillaris pars rostralis (7) is filled with soft tissue dens material. There is a mucosal thickening in the sinus conchae ventralis (8) and the sinus conchae dorsalis (9).

Figure 3:



Transverse CT image at the level of the second molar teeth (laterorostral root) in a 8-year-old thoroughbred with anamnestic malodorous nasal discharge on the left side since 3 months. There is a severe apical infection of 110 (laterorostral root) with a tooth fracture (1), fracture and clubbing of the root (2), pulpitis (3), widened periodontal space (4) and loss of lamina dura (5). There is a hypoattenuating rostral infundibulum bilaterally (6). In the sinus maxillaris pars rostralis, there is mucosal thickening or a small cyst on the right (7) and a fluid level on the left (8).

Figure 4:



Transverse CT image at the level of the first molar teeth (medial and laterocaudal root) in a 4-year-old thoroughbred with nasal discharge and facial swelling since 3 days. There is severe apical infection of 109 (medial and laterocaudal root) with clubbing of the root (1), pulpitis (2), widened periodontal space (3) and loss of lamina dura (4). There is a slight hypoattenuating caudal infundibulum bilaterally (5). The sinus maxillaris pars rostralis (6) is filled with soft tissue dens material and osteitis (7) of the maxillary bone with facial soft tissue swelling (8) is present.

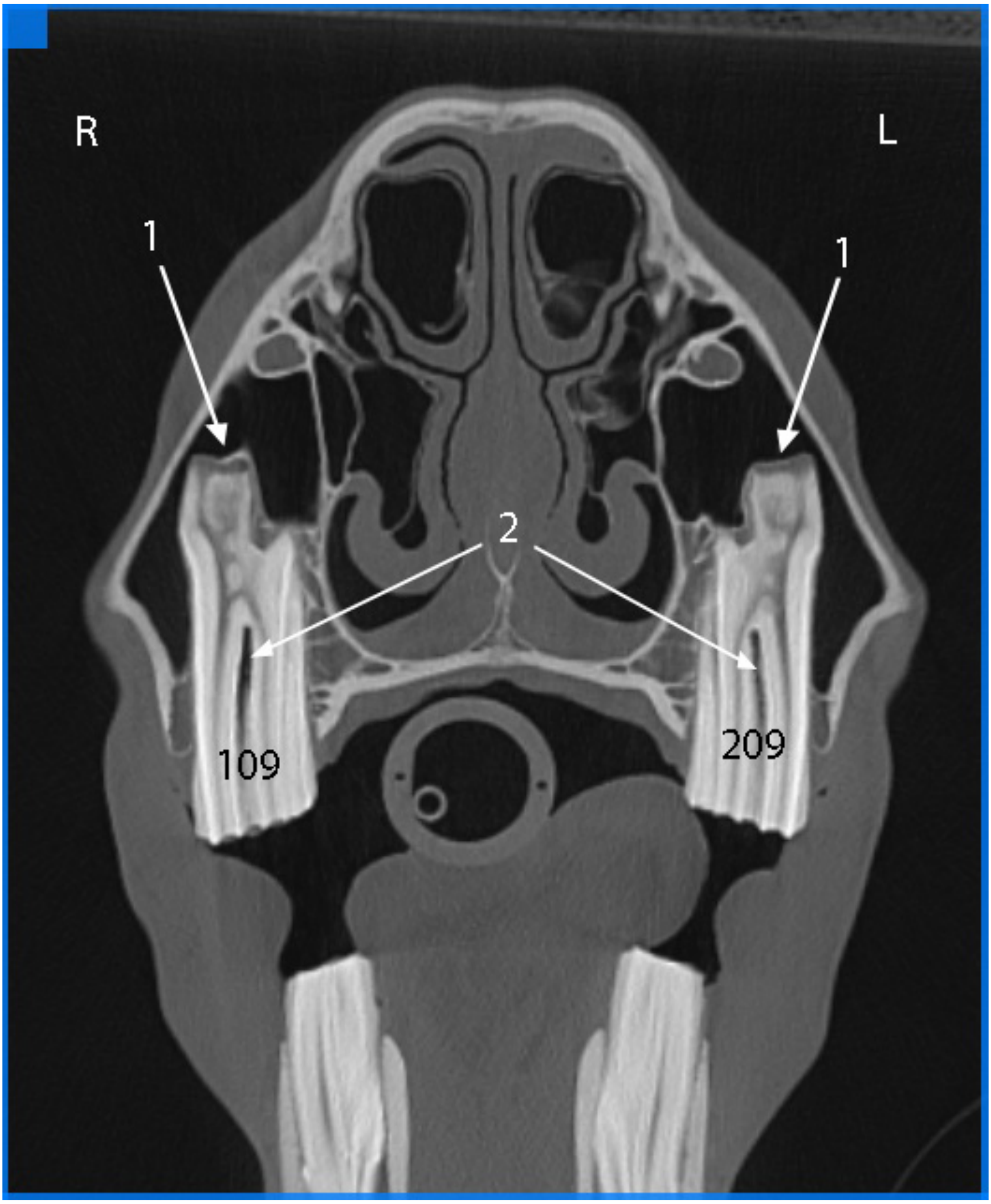
Figure 5:

Transverse CT image at the level of the first molar teeth (laterocaudal root) in a 8-year-old warmblood. At the 109 and 209 the lamina dura is absent (1). There are no other signs of dental disease.

Figure 6:

Transverse CT image at the level of the second premolar teeth (medial root) in a 12-year-old warmblood. The lamina dura is incomplete (2), however, there are no other signs of periodontal disease.

Figure 7:



Transverse CT image at the level of the first molar teeth (laterorostral root) in a 10-year-old warmblood. The lamina dura is intact and complete (1) and no other signs of periodontal disease are present except hypoattenuating rostral infundibula (2).

2.8.2 Tables

Table 1: Absolute frequency of computed tomography abnormalities in 1764 roots and 1176 infundibula of 588 upper cheek teeth in 49 horses

Tooth (Triadan system)	**106**	**107**	**108**	**109**	**110**	**111**	**206**	**207**	**208**	**209**	**210**	**211**	**Total**
Infundibular necrosis													
Rostral	15	15	9	30	25	1	16	15	8	34	27	1	196 inf. (16.7%)
Caudal	4	5	6	28	8	0	3	3	7	25	8	0	97 inf. (8.2%)
Tooth fracture	0	1	2	1	2	0	0	0	1	1	1	0	9 teeth (1.5%)
Pulpitis	2	1	1	2	1	0	1	0	1	5	1	0	15 teeth (2.6%)
Clubbing of the root													29 roots (1.6%)
Rostral root	0	0	0	0	2	0	0	0	2	1	1	0	
Medial root	0	0	1	1	1	0	0	0	1	3	4	0	
Caudal root	0	0	1	2	2	0	0	0	1	3	3	0	
Loss of lamina dura													1338 roots (75.9%)
Rostral root	40	40	31	36	37	40	41	38	35	36	35	36	
Medial root	47	46	33	27	34	25	46	47	38	32	38	29	
Caudal root	46	47	30	28	36	34	44	46	35	30	41	34	
Alveolar bone sclerosis													120 roots (6.8%)
Rostral root	1	1	3	8	6	4	0	0	3	6	6	3	
Medial root	1	1	4	7	6	2	0	1	5	7	6	3	
Caudal root	1	1	4	7	5	1	0	0	3	8	4	2	
Widened periodontal space													43 roots (2.4%)
Rostral root	0	0	1	4	2	0	0	1	2	2	1	0	
Medial root	0	0	2	2	3	1	0	1	3	4	3	0	
Caudal root	0	0	1	2	2	0	0	1	0	3	2	0	

Table 2: Results of the mixed models for the various CT signs of periodontal disease (only the significant covariates are shown)

Dependent variable	Significant covariate(s)	Estimate (B-value)	*p*-value
Infundibular necrosis	Tooth fracture	-2.6076	0.001
Tooth fracture	Infundibular necrosis	-2.6378	0.017
	Pulpitis	4.1359	< 0.001
	Alveolar bone sclerosis	2.6264	0.003
Pulpitis	Tooth fracture	8.564	< 0.001
	Alveolar bone sclerosis	6.566	< 0.001
Clubbing of the root	Tooth fracture	3.3498	0.02
	Alveolar bone sclerosis	2.704	< 0.001
	Widened periodontal space	2.1618	0.004
Loss of lamina dura	Pulpitis	1.5878	0.004
	Widened periodontal space	-1.0131	0.01
Alveolar bone sclerosis	Pulpitis	3.9404	< 0.001
	Clubbing of the root	2.3817	0.0038
	Widened periodontal space	5.8453	< 0.001
Widened periodontal space	Clubbing of the root	2.3851	< 0.001
	Alveolar bone sclerosis	5.081	< 0.001